

Translocation, Homing Behavior and Habitat Use of Groundfishes Associated with Oil Platforms in the East Santa Barbara Channel, California

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Abstract.—All offshore oil and gas platforms have finite economic life spans. One of the decommissioning options for these platforms is complete removal, requiring the use of explosives to dislodge the support structure from below the seafloor. Off California, this decommissioning option would kill large numbers of platform-associated and commercially important groundfishes that inhabit the bases of the platforms, and may potentially affect regional fish populations. Capturing and translocating fishes before removing a platform might mitigate the effects of platform removal. In this study, we acoustically tagged 79 rockfishes and lingcod from three oil platforms in the east Santa Barbara Channel and translocated them to a natural reef inside a state marine reserve at Anacapa Island to determine whether individuals would home back to their platforms of capture, or take up residency at their new location. Movements between natural and platform habitats were monitored over a two-year period. Twenty-five percent of all tagged fishes translocated to a natural reef returned to their home platforms relatively quickly, traveling distances from 11 km to ≥ 18 km, in 10.5 h to 17 d. Those that did not home took up residency at Anacapa Island, moved to Santa Cruz Island or out of the range of detection. Although a small proportion of fish (25%) homed back to the platforms, a higher proportion (75%) remained at their platforms of release. Those that homed back to their platform of capture did so relatively quickly (avg 15 ± 31 d). Lingcod had the highest probability of homing back to their platform of capture, typically doing so in < 1 day. These results suggest that fish translocation may be a successful, but costly mitigation strategy for platforms that require full decommissioning and that some species may be more successfully translocated than others.

Introduction

In California, offshore oil platforms have accumulated a broad array of marine life from the surface to the seafloor in areas that are otherwise depauperate of natural reef or complex structure. Platforms in the Santa Barbara Channel have been found to function as *de facto* reserves protecting several species of groundfishes from fishing pressure that has resulted in their localized depletion on natural, unprotected reefs (Helvey 2002, Love et al. 2003). Until recently, all obsolete platforms off California required full decommissioning,

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resulting in the removal of the entire structure to 4.5 m below the seafloor and subsequent restoration of the seafloor to its original state (Schroeder and Love 2004). In the Gulf of Mexico, widespread support of coastal states led to a federal Rigs-to-Reefs program (Dauterive 2000), designed to support the sportfishing and recreational diving industries by creating a network of artificial reefs from the partial removal and toppling of obsolete oil platforms. Platform reefing in California has been a controversial issue, but a new State policy now allows for partial removal (California Marine Resources Legacy Act 2010). However, not all platforms will be considered for reefing under the new policy; the effects of the decommissioning process on marine life associated with those platforms need further evaluation.

Full removal of an obsolete platform will result in a complete loss of complex habitat and its associated marine community. While a majority of sessile organisms are lost as a result of full platform removal, mobile species have the capability to relocate during the decommissioning process. However, one method frequently utilized for full removal includes the use of explosives to sever the support structure below the seafloor (Schroeder and Love 2004), which results in large mortalities of fishes with swim bladders that reside around platforms (Bull and Kendall 1994). In this case, a majority of fish are killed before they have a chance to move away during the structure removal process. One potential mitigation option would be to translocate platform-associated fishes away from the platform prior to the implementation of explosives. However the success of translocation is dependent on the degree of site fidelity and movement of the species associated with the platform.

Platform surveys have shown that groundfishes observed around oil platforms are closely associated with the structure (Love et al. 2003). Typically, species like benthic rockfishes (*Sebastes* spp.) and lingcod (*Ophiodon elongatus*) that have a high affinity for complex substrata, also have small home ranges and exhibit high site fidelity (Matthews 1990ab, Starr et al. 2002, Lowe and Bray 2006). Lowe et al. (2009) found that some species of rockfish exhibited moderate to high degrees of site fidelity on offshore oil platforms with probable ontogenetic emigration. Therefore, translocation of residents could result in individuals “homing,” defined as the ability to return to a home range after leaving or being displaced (Gerking 1959).

Despite a high degree of site fidelity, tagging studies have also demonstrated that rockfishes and lingcod are capable of moving significant distances over natural reefs and along coastlines. Previous displacement studies of rockfishes have indicated that they are capable of homing from 400 m to over 22 km (Matthews 1990ab, Pearcy 1992, Lea et al. 1999) and lingcod have been shown to home from distances of ~8 km (Lowe et al. 2009). Previous translocation experiments released tagged reef associated fishes over contiguous habitat, in relatively shallow depths and primarily along a coastline, all of which offer navigational aids to return. None have challenged homing ability by releasing fish in high-relief rockfish habitat or across distances and depths that exceed their known limits.

If full removal of some offshore platforms using explosives is to remain an option, translocating a proportion of the fish population to natural reefs as a mitigating alternative may be viable assuming a majority do not home back to the platform. Therefore, it is important to determine whether platform-associated groundfishes home after displacement. The goals of this study were to (1) determine whether platform-associated fishes would home back to resident oil platforms after being translocated to a natural reef, and (2) characterize patterns of movement on and between platform and natural reef habitats.

Methods

Study Site

The Santa Barbara Channel is bound on the south by the Northern Channel Islands (Anacapa, Santa Cruz, Santa Rosa, and San Miguel) and is approximately 100 km long and 50 km wide with seafloor depths exceeding 230 m mid channel (Fig. 1). Oil platforms Gail (225 m depth), Gilda (61 m), and Grace (91 m) are situated in the east Channel approximately 11 km, 17 km, and 18 km away from northeast Anacapa Island, respectively, and range from 5–8 km apart from each other. Most of the seafloor in the east Santa Barbara Channel consists of sand and mud habitat, so offshore oil platforms throughout this part of the Channel may constitute significant fish habitat.

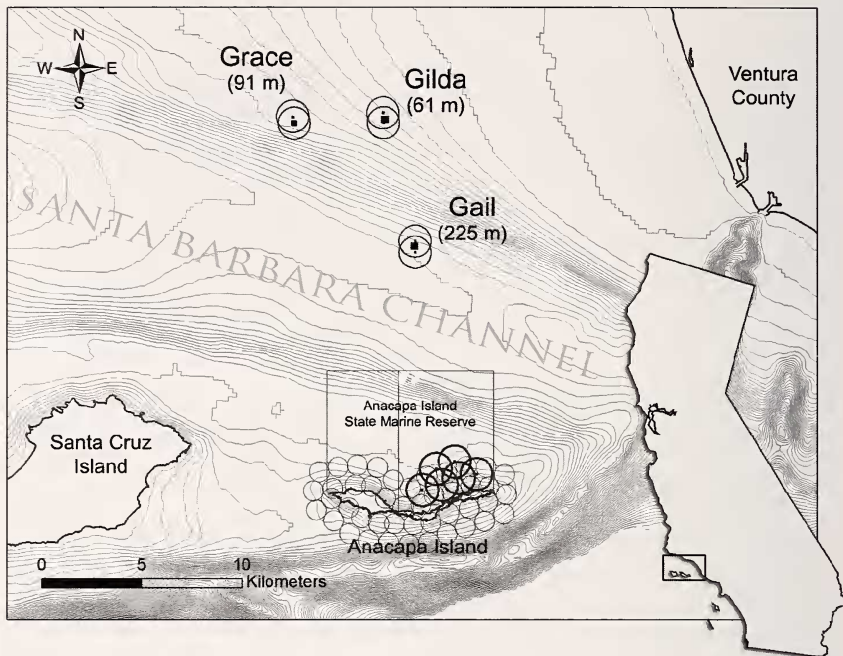
Tagging

All fishing was conducted from an 8 m vessel, which allowed for close access to the platform structure. While fishing on and near the seafloor in depths ranging from 61 to 225 m, fishes were caught on conventional hook and line using baited circle hooks. Once landed, fishes were held in the vessel's live well in chilled ($10^{\circ} \pm 2^{\circ}$ C) seawater. The condition of all fishes was assessed upon landing. Most were afflicted with some form of barotrauma, or a combination of signs (e.g., distended abdomen, exophthalmia, air bubbles under skin, or stomach protruded through mouth). Fishes judged to be in good condition and with milder signs of barotrauma were held for tagging (Fig. 2). To minimize handling time and risk of puncturing vital organs, swim bladder venting with hypodermic needles was not performed—the surgical incision typically released an adequate amount of pressure. Fishes were surgically fitted with V13 R-code acoustic transmitters (model V13-1H-R04K, 156 dB power output, 13 mm diameter \times 36 mm length; Vemco, Halifax, Nova Scotia, Canada), which were coated in a blend of paraffin and beeswax (2.3:1.0) to prevent immunorejection (Lowe et al. 2003). Transmitters emitted a 69 kHz pulse train pseudo-randomly in 150 to 300 s intervals, which allowed for a nominal battery life of \sim 4 yr. The pulse train contained information unique to the identification code for each transmitter. Prior to tagging surgery, fishes were anaesthetized in a cooler containing chilled seawater (\sim 10 $^{\circ}$ C) with 20 ppm clove oil and measured for total lengths (cm). A 1.5 cm incision was made approximately 1 cm from the ventral midline of the fish, between the pelvic fins and the anal vent through the peritoneum. A V13 transmitter was inserted into the abdominal cavity and the incision was closed with one or two interrupted dissolvable sutures (Ethicon Chromic Gut, Johnson & Johnson). An external identification tag was inserted into the dorsal musculature of each fish in the event that an individual was recaptured by an angler, or sighted during submersible surveys. Fishes were subsequently held on the vessel's chilled seawater live well for transport. Moribund fishes were euthanized and kept for other research purposes (Rogers et al. 2008), and live fishes too small for tagging were released to a depth of 35 m in an inverted, weighted milk crate (Jarvis and Lowe 2008) at the site of capture.

Acoustic Receiver Deployment

Automated omni-directional acoustic receivers (VR2, Vemco Ltd.) were deployed on each of the three oil platforms' north and south mooring buoys as described by Lowe et al. (2009). Due to security restrictions, VR2 receiver deployment was not possible at Platform Gilda until 20 October 2006, over 2 mo after the initial deployment of all other

a.



b.

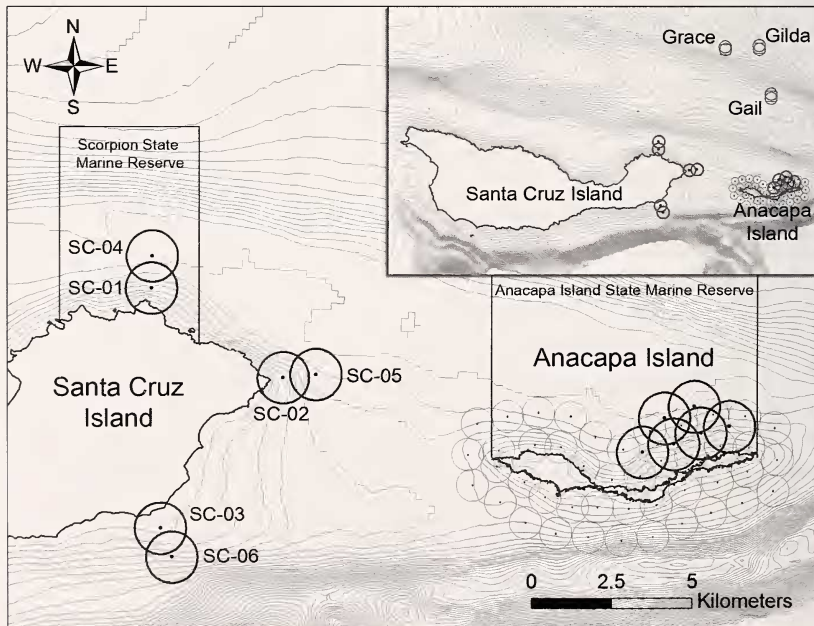


Fig. 1. Inset of panel (a) shows the study site offshore Ventura County, California in the Santa Barbara Channel. Panel (b) details the study site between the east end of Santa Cruz Island and Anacapa Island. Circles surrounding the dots at each oil platform and at Anacapa Island characterize 800 m detection zones around each VR2 receiver. Smaller, faded circles in a two-tiered array around Anacapa Island depict 500 m detection zones around VR2 receivers maintained by the Pflieger Institute for Environmental Research (PIER) through October 2006. Depth contours are 10 m.

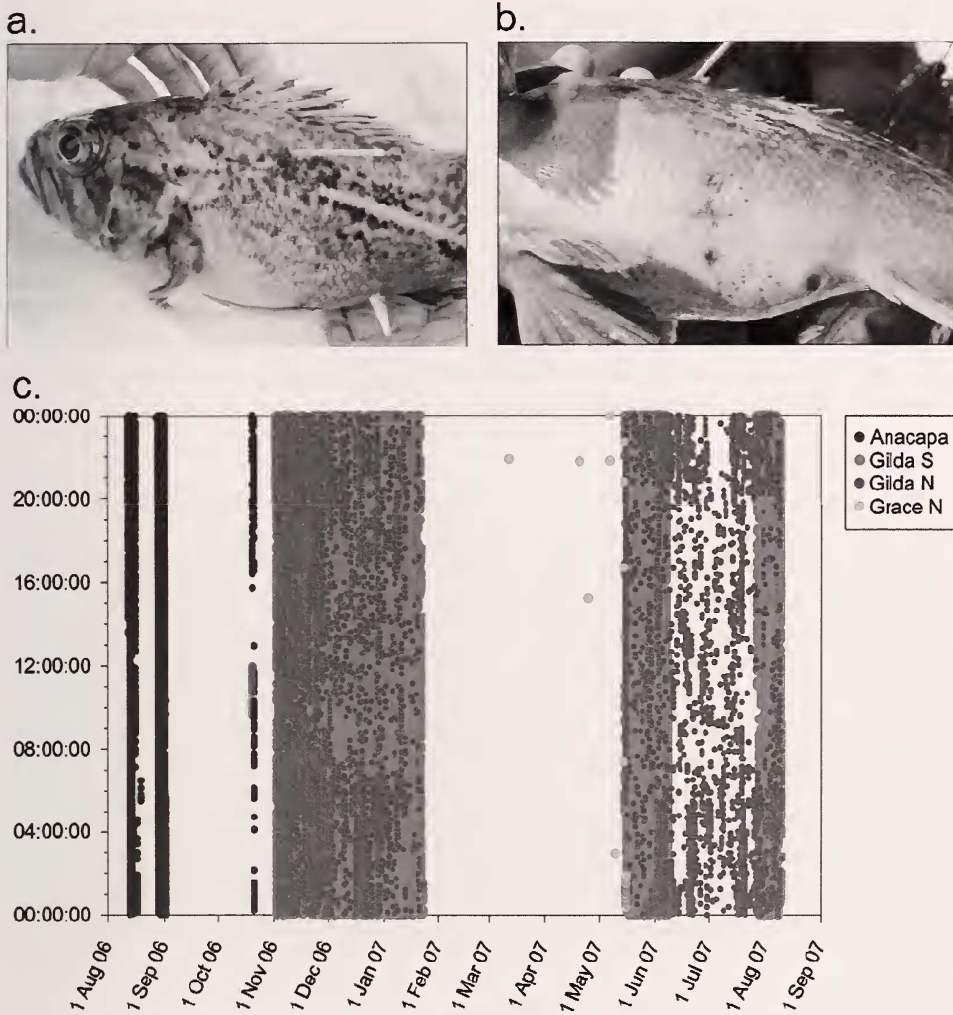


Fig. 2. Recaptured tagged vermilion rockfish showing (a) an external ID tag and (b) ventral view of a healed surgical incision. Panel (c) shows the date-time scatter plot of individual SMIN 3784, detected at Anacapa Island and subsequently at Platform Grace, where it was recaptured and translocated to Anacapa for a second time.

receivers. VR2 receivers were estimated to have a detection range of approximately 800 m, based on range tests performed with V13 transmitters before any fish was tagged and released. Two VR2 receivers deployed on the north and south sides of each platform provided a detection coverage area around the jacket of approximately 1 km². VR2 receivers recorded and stored the date and time of detection and the unique identification code of each fish if the transmitter emitted a signal inside the detection range. Previous studies at Platforms Gilda, Grace and on the San Pedro shelf have found no indication of diel ambient noise that would confound interpretation of diel activity/detection patterns (Lowe et al. 2009; C. Mireles Unpub. Data).

The northeast side of Anacapa Island was chosen as a natural reef site to translocate fishes because of its accessibility, its historically rich rockfish abundances and because the

location is a state marine reserve, which offers protection from fishing pressure. VR2 receivers were deployed at depths from 55 m to 80 m, comparable to two of the three oil platforms of study. Depths of receivers deployed at Anacapa Island exceeded safe scuba diving limits, therefore VR2 receivers were retrieved from depth using acoustic releases (AR-50 Sub Sea Sonics, San Diego). Once released from the sand bag anchor, the VR2 receiver-acoustic release unit floated to the surface for recovery. The Pflieger Institute of Environmental Research (PIER) maintained an array of VR2 acoustic receivers around Anacapa Island and the east end of Santa Cruz Island, which also detected any tagged fishes for this study that moved within detection range of those receivers.

VR2 receivers were retrieved and downloaded every 2 mo as weather permitted and rebatteried every 6 mo over the 620 d study period. Several VR2s were either lost or could not be deployed due to either mechanical error or strong swell events; gaps in data are indicated where these events occurred.

Translocations

Data collection began with the release of tagged fishes at Anacapa Island on 6 Aug 2006 and ended 12 April 2008 when all VR2 receivers were permanently pulled from their stations. Rockfishes and lingcod were tagged and translocated from Platforms Gail (lingcod only), Gilda and Grace to the northeast side of Anacapa Island inside the state marine reserve (Fig. 1). The distances from each oil platform to the site of release at Anacapa Island were approximately 11 km, 17 km and 18 km from Platforms Gail, Gilda and Grace, respectively, resulting in transport times ranging from 15 to 45 min depending on sea conditions. Initially at the release site, tagged fish were lowered in a 1 m³ vinyl-coated mesh cage to the seafloor at 58 m and held there overnight to confirm survival. The following morning, the cage was pulled to 18 m depth and met by a team of divers who assessed the fishes' condition; divers released healthy-looking, actively swimming individuals. Based on evidence of successful survivorship following cage observations, after 23 September 2006, all tagged fishes were released at Anacapa Island without being held in a cage and were thereafter assisted to the bottom from the surface in an inverted weighted milk crate, allowing them to swim away on their own.

Data Analysis

Transmitter deployment (i.e., fish release) spanned two consecutive summers (2006–2007), thus data were standardized from the day each fish was released, defined as “days since released.” A fish was considered present at any given location if it was detected on a receiver at least three times in one day within one hour. Based on those criteria, telemetry data were used to determine (1) whether fish homed, (2) the residence time at any given location, (3) transit times and (4) temporal patterns in detection. Emigration rates of tagged fishes in this study were characterized using a logarithmic equation (Lowe et al. 2009). Working from the same oil platforms as the current study, Lowe et al. (2009) tagged rockfishes and lingcod and released them onsite; the study served as a control and was used for comparison of emigration rates from the translocation site (Anacapa Island). Residence time was defined as the time an individual spent at its site of release before moving outside the range of detection. An individual was characterized as having taken up residency if it was detected at the same site consistently for at least 2 mos. The time elapsed from the site of release to an oil platform or other monitored location was considered transit time. Residence and transit times were compared among species. Differences in residence times of fishes at Anacapa Island were tested using a Mann-Whitney rank sum test. Two-sample

Table 1. Tagging summary of all fishes translocated from platforms Gail, Gilda, or Grace to a natural reef inside Anacapa Island State Marine Reserve. Total lengths (TL) were measured in cm.

Common Name	Species	Species Code	Size Range (TL in cm)	Platform (# of fish)		
				Gail	Gilda	Grace
Lingcod	<i>Ophiodon elongatus</i>	OELO	66.0–94.0	10	-	-
Mexican rockfish	<i>Sebastes macdonaldi</i>	SMAC	51.0	1	-	-
Greenblotched rockfish	<i>Sebastes rosenblatti</i>	SGBL	35.0	1	-	-
Brown rockfish	<i>Sebastes auriculatus</i>	SAUR	30.0, 37.0	-	2	-
Vermilion rockfish	<i>Sebastes miniatus</i>	SMIN	24.0–35.5	-	7	30
Copper rockfish	<i>Sebastes caurinus</i>	SCAU	25.5, 44.0	-	2	4
Widow rockfish	<i>Sebastes entomelas</i>	SENT	27.0–31.0	-	-	4
Squarespot rockfish	<i>Sebastes hopkinsi</i>	SHOP	28.2, 28.7	-	-	2
Blue rockfish	<i>Sebastes mystinus</i>	SMYS	27.0–34.0	-	-	5
Bocaccio	<i>Sebastes paucispinis</i>	SPAU	28.5–32.0	-	-	5
Flag rockfish	<i>Sebastes rubrivinctus</i>	SRUB	23.6–28.2	-	-	5
Starry rockfish	<i>Sebastes constellatus</i>	SCON	27.0	-	-	1

t-tests were used to (1) determine whether there was a difference in the size of fish that homed and (2) discern differences in transit time from Anacapa Island to platforms.

By determining the presence and absence of an individual on a day-to-day basis, a probability of detection was calculated for each combination of monitored locations (e.g., Anacapa to Gail, Gail to Grace, Grace to Anacapa, etc.) for each species. This calculation was adapted from probability matrix models developed by Gotelli (2001). According to Lowe et al. (2009) fishes tagged on the same offshore platforms exhibited movement away from the platforms within 175 d of their release. For this model, we predicted a period of movement within 200 d of their release over the 620 d monitoring period. Thus, the probabilities of movement (we termed these *probability matrix loops* to reflect movement amongst monitored sites) were calculated out to 200 d for vermilion rockfish and lingcod. Assuming the ability of a fish to be detected was equal at all VR2 receivers, the probability of detection was used as a probability of movement to a different monitored location.

Results

Acoustic data were analyzed for 79 individuals tagged and translocated from oil platforms Gail, Gilda and Grace to Anacapa Island (Table 1). A greater proportion of fishes did not home, but 25.3% of individuals (11 rockfishes, 9 lingcod) returned to the oil platforms of their original capture. Although one brown rockfish (*S. auriculatus*) homed back to Platform Gilda, statistical analyses focused on the vermilion rockfish and lingcod. One previously tagged vermilion rockfish (SMIN 3784, Table 2) was recaptured at Platform Gilda, but the time of arrival at the platform could not be determined due to the absence of VR2 receiver coverage there until the day it was recaptured on 20 Oct 2006 (Fig. 2ab). This fish displayed minor signs of barotrauma (slightly distended eyes and bloated abdomen) upon recapture, but appeared to be in good physical condition when taken back to Anacapa Island for a second time. Twelve days later on 2 Nov 2006, the same individual (SMIN 3784) arrived at Platform Gilda again until 23 Jan 2007. After a period of absence (nearly 4 mo), this fish was once again detected at Platform Grace until 16 May 2007 (Fig. 2c). It was last detected at Platform Grace on 16 May 2007 at 01:52 h and moved back to Platform Gilda at 05:00 h the same day.

Table 2. Summary of all fishes that homed after translocation from platforms Gail, Gilda, or Grace to Anacapa Island. Each species is represented by a shorthand code and unique ID number.

Common name (Genus species)	Platform	Code	TL (cm)
Lingcod (<i>Ophiodon elongatus</i>) <i>N</i> = 9 out of 10	Gail	OELO 3704	84.0
		OELO 3719	82.0
		OELO 3733	78.0
		OELO 3736	94.0
		OELO 3742	65.0
		OELO 3767	90.0
		OELO 3777	89.0
		OELO 3781	89.5
		OELO 3787	74.0
Brown rockfish (<i>Sebastes auriculatus</i>) <i>N</i> = 1 out of 2	Gilda	SAUR 3783	37.0
Vermilion rockfish (<i>Sebastes miniatus</i>) <i>N</i> = 10 out of 30	Grace	SMIN 3743	33.0
		SMIN 3752	35.3
		SMIN 3758	35.3
		SMIN 3768	34.0
		SMIN 3771	27.5
		SMIN 3784	29.0
		SMIN 3785	30.2
		SMIN 3790	32.0
		SMIN 3795	32.0
	SMIN 3797	33.8	

Some catch and release mortality was expected from the time of release up to approximately 10 d (Lowe et al. 2009), as indicated by an initial sharp decline in the number of fishes detected at Anacapa Island; however, some of this decline was coupled with a concomitant increase in the number of fishes detected at the platforms (Fig. 3). Three VR2 receivers were lost at Anacapa Island between 22 Sep 06 and 20 Dec 06, but immediately after they were replaced (20 Dec 06, near day 145), the number of fishes detected increased. The initial rapid decline in the number of fishes detected during the first 15 d since release (-3.50 fish/d) was attributed to mortality and/or immediate emigration from Anacapa Island. By the time the last individual homed (47 d), emigration rates slowed to -0.193 fish/d until 55 d, then stabilized to -0.026 fish/d from 140 d through the end of the study. A logarithmic equation best described the decrease in the number of fishes detected at Anacapa Island over the course of the study period (Fig. 3) ($y = -5.1964\ln(x) + 38.118$; $R^2 = 0.6278$).

Straight line distances from the site of release at Anacapa Island to each of the three platforms were the assumed minimum distance homing routes (Fig. 4). Lingcod traveled a minimum distance of 11 km back to Platform Gail, vermilion rockfish moved 18 km to Grace, and one brown rockfish moved 17 km to Gilda. One vermilion rockfish (SMIN 3795) was detected at Platform Gail before returning to Grace, increasing its homing distance by 1 km (19 km total).

All fishes that homed did so in a mean (\pm SD) of 14.7 ± 30.6 d after their release, and their residence times ranged from <1 to 47 d (Fig. 5a). Lingcod spent significantly less time at Anacapa Island before homing than did vermilion rockfish ($W = 55.0$, $p = 0.005$, $df = 17$). Lingcod had the shortest mean transit time (1.4 ± 1.22 d) with the fastest

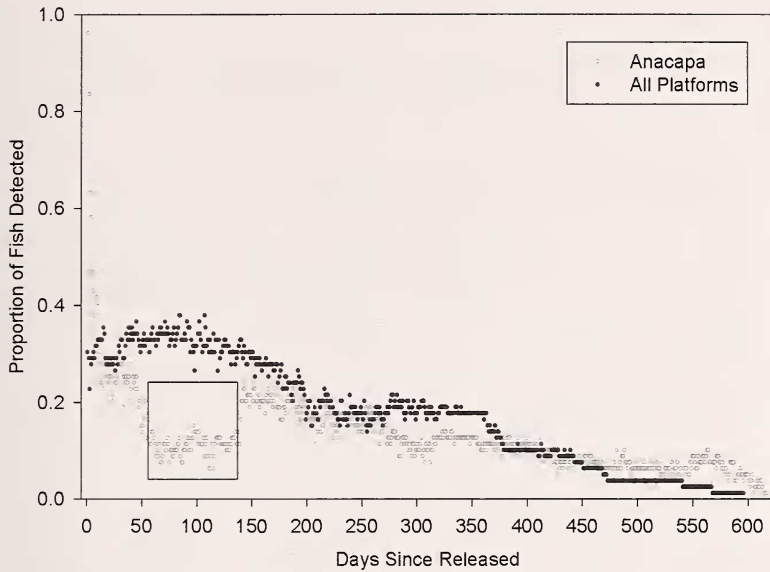


Fig. 3. Proportion of tagged rockfishes and lingcod detected inside the VR2 acoustic array at Anacapa Island (gray dots) and at all three oil platforms (black dots) each day since fishes were released. The black box surrounds detections spanning 88 d where three VR2 receivers were lost at Anacapa Island.

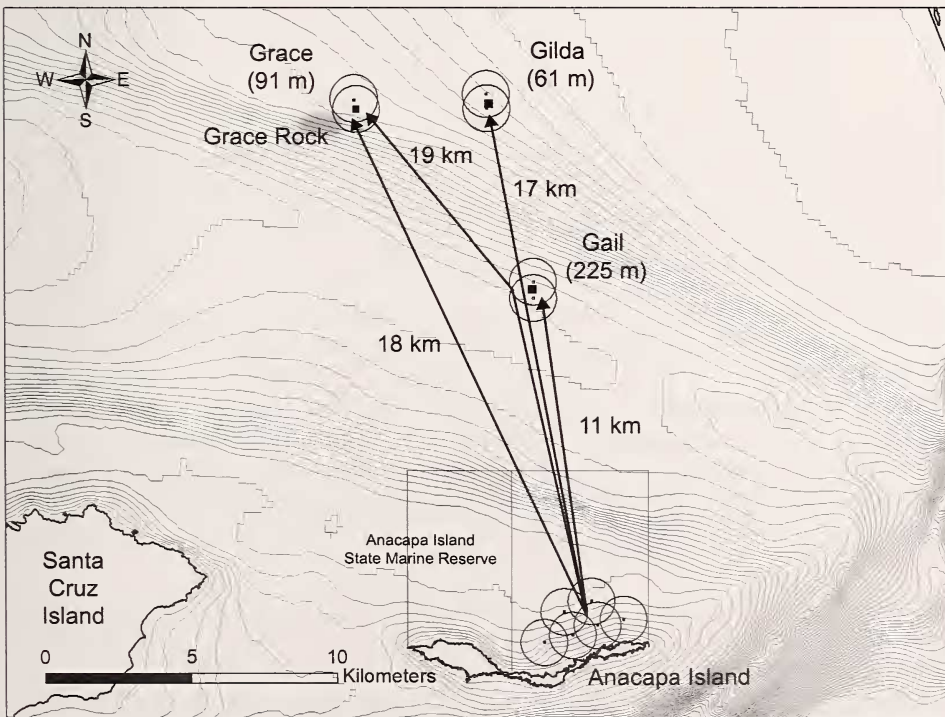


Fig. 4. Map showing minimum distance travel routes (in km) for individuals that homed after translocation. Depths of each platform are indicated in parentheses. Depth contours are in 10 m increments. Circles indicate 800 m detection zones around each of 12 stationary VR2 receivers (black dot).

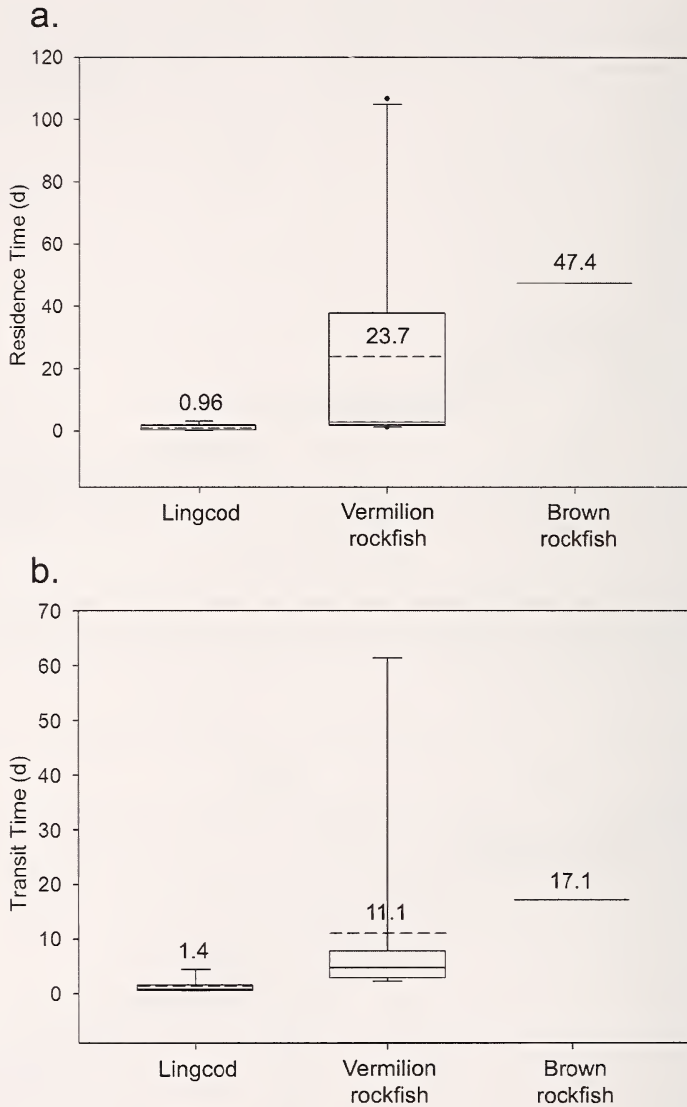


Fig. 5. Box plots of (a) presence times (in days) and (b) transit times for lingcod, vermilion rockfish, and one brown rockfish that homed back to their oil platforms of capture. Values shown are means, which are also indicated by the dotted line, except for the brown rockfish, for which only one individual homed. Upper and lower hinges represent 75th and 25th percentiles, respectively, while the median is shown as a solid line inside the box (visible only for vermilion rockfish). Vertical bars show the minimum and maximum values with outliers indicated by black dots.

individual homing 11 km in 10.5 h (Fig. 5b). Rockfish that homed were larger (32.6 ± 2.88 cm TL (\pm SD)) compared to those that did not (30.2 ± 4.32 cm TL) ($p = 0.04$, $df = 67$, $t = 1.8$).

Movement patterns were idiosyncratic and no one pattern was attributable to a given species. Some individuals exhibited diel patterns in movement upon return to the platforms, e.g., vermilion rockfish SMIN 3771 was detected on both north- and south-stationed VR2 receivers, showing a higher concentration of detections between 06:00 h



Fig. 6. Daily detection plot of all fish that homed: vermilion rockfish (SMIN), brown rockfish (SAUR), and lingcod (OELO). For each individual along the y-axis, a shaded mark exists for each date (x-axis) it was detected at Anacapa, Platforms Gail, Gilda or Grace. The gray diamond on the last day of SAUR 3783 indicates that the fish was relocated during mobile acoustic surveys with the VR100, after months of remaining undetected by the stationary VR2 receivers. Vermilion SMIN 3784 homed to Platform Gilda and was subsequently recaptured in Oct. 2006. It was taken to Anacapa Island for a second time and homed again, back to Platform Gilda.

and 19:00 h on the south side of Platform Grace. One vermilion rockfish and three lingcod exhibited movement between platforms after returning to their home platforms (Fig. 6). Two vermilion rockfish (SMINs 3795 and 3790) were detected at Platform Gail before homing to Platform Grace, traveling at least 19 km. SMIN 3784 (Fig. 3) homed to Platform Gilda from Anacapa Island twice, moved to Platform Grace then back to Platform Gilda, traveling a total distance of 27 km. Lingcods OELO 3787 and OELO 3777 homed from Anacapa Island to Platform Gail, moved to Platform Grace and subsequently returned to Platform Gail, each moving a minimum of 27 km. OELO 3767 traveled 35 km, having homed to Platform Gail, moved to Platform Grace and returned to Platform Gail, but moved to Platform Grace 14 d before going undetected. After homing to Platform Gail, OELO 3704 moved back to Anacapa Island for nearly 4 mo before returning to Platform Gail for 21 d, then moved back to Anacapa Island, traveling a distance of at least 44 km. From early March 2008 through the remainder of the study, this lingcod was detected at Anacapa Island.

Non-homing fishes

Fifty-nine individuals did not home and were either detected within the Anacapa Island VR2 receiver array or moved out of the range of detection for some portion or during most of the 620 d monitoring period. Fishes that did not home included bocaccio (*S. paucispinis*), Mexican rockfish (*S. macdonaldi*), greenblotched (*S. rosenblatti*), starry (*S. constellatus*), copper (*S. caurinus*), brown (*S. auriculatus*), squarespot (*S. hopkinsi*), widow (*S. entomelas*), blue (*S. mystinus*), flag (*S. rubrivinctus*), 27 vermilion rockfish and one

lingcod. While many individuals went undetected after variable amounts of time after release (days to months), 12 individuals continued to be detected very close to, or through the end of the study period, indicative of residency.

Two examples of fishes that appeared to take up residency within the Anacapa Island VR2 array were a flag rockfish (SRUB 3734) and a bocaccio (SPAU 3760); they showed clear movements based on their detections between at least two VR2 receivers. Flag rockfish SRUB 3734 revealed considerable movement between several VR2 receivers, including those of PIER. Shortly after their release at Anacapa Island, a flag (SRUB 3746, 25.0 cm TL), a blue (SMYS 3748, 32.7 cm), and a vermilion (SMIN 3751, 29.5 cm) rockfish moved to Santa Cruz Island, where they were detected by VR2 receivers maintained by PIER. These three fish remained at Anacapa Island from 2–7 d before they moved out of the range of detection and were subsequently detected at PIER receivers SC-01 and SC-04 inside the Scorpion State Marine Reserve (Fig. 1b). Although four additional VR2 receivers were deployed around the east end of Santa Cruz Island, no individuals were detected at those locations. VR2 receivers were removed by PIER in Oct. 2006, therefore it was impossible to know if any fishes thereafter moved to Santa Cruz Island.

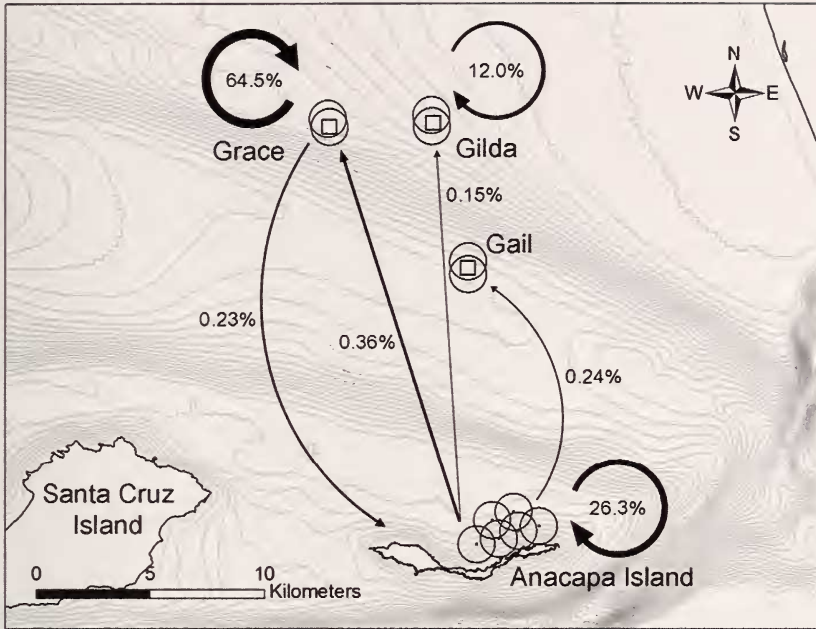
Vermilion rockfish that homed exhibited seven patterns of behavior, all starting at Anacapa and moving (1) to Grace, (2) to Gilda, (3) to Gail, (4) from Grace to Anacapa, (5) remaining at Anacapa, (6) remaining at Gilda and (7) remaining at Grace (Fig. 7a). Vermilion rockfish caught from Platform Grace were most likely to stay there if they returned (64.5% probability). Alternatively, fish that were translocated to Anacapa Island had a 26.3% probability of staying inside the acoustic receiver array there. The third site most frequently visited by vermilion rockfish was Platform Gilda, where the probability of fish remaining there was 12%. Ten of 37 (27%) vermilion rockfish successfully homed, of which 40% ($n = 4$ of 10) visited Platforms Gail, Gilda or Anacapa Island before returning to Platform Grace.

Lingcod moved to either Anacapa Island or Platform Gail (Fig. 7b), regardless of where they were detected previously. Lingcod had the highest probability of being detected at Platform Gail (77.3%), or Anacapa Island (22.3%). To a much lesser extent, fish moved to Anacapa Island or Platform Gail from all other locations ($\leq 1.18\%$).

Discussion

The ability to return to a home range after displacement, or homing, is a well-documented phenomenon in fishes (Carlson and Haight 1972; Hallacher 1984; Markevich 1988; Matthews 1990ab; Pearey 1992; Hartney 1996; Lea et al. 1999; Marnane 2000; Kaunda-Arara and Rose 2004; Starr et al. 2004). One of the earliest reports of homing in rockfishes was described by Carlson and Haight (1972), who displaced yellowtail rockfish (*Sebastes flavidus*) off southeast Alaska from their site of capture and reported tagged individuals that had homed back, including one individual that returned from 22.5 km. With the exception of Carlson and Haight (1972), previous displacement studies have tested homing ability within contiguous habitat or along a depth contour, thus providing a habitat boundary to follow. Fishes in the current study were translocated from their sites of capture offshore across a channel basin (>200 m depth). Despite these potential physical barriers, lingcod, vermilion rockfish and one brown rockfish successfully homed back to their platforms of capture, but also exhibited movement around, away from and between platforms after homing events.

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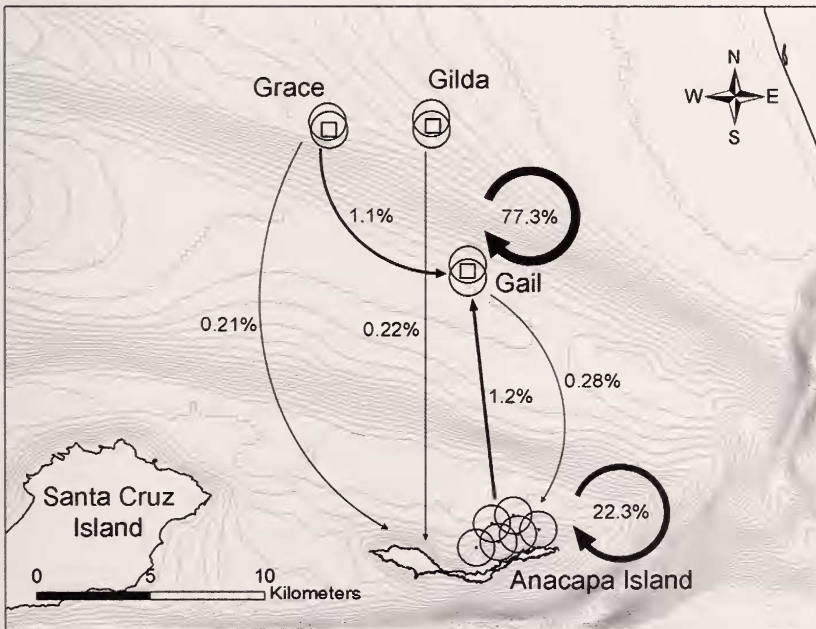


Fig. 7. Probability matrix loops for (a) vermilion rockfish and (b) lingcod movement overlaid on a GIS map for each site monitored during the study period. Probabilities of movements were calculated over a 200 d period. Thicker lines emphasize increased probability of movement in the direction of the arrow.

Tagged rockfishes and lingcod removed from offshore oil platforms and translocated to natural habitat at Anacapa Island exhibited the ability to home across previously unrecorded distances and in a relatively short time periods to their platforms of capture. Following release at Anacapa Island, the proportion of tagged fishes detected rapidly declined in the first 10 d, reflecting a departure from the receiver array coupled with some probable post-release mortality. Because detections at all three oil platforms subsequently increased, some of the immediate decline in detections of tagged fish at Anacapa Island during the first 50 d represents individuals that homed back to the platforms. Furthermore, a decrease in the proportion of fishes detected after 50 d was compounded by the temporary loss of three VR2 receivers at Anacapa Island. Although there was a steady decline in the number of fishes throughout the study period, the proportion detected at both Anacapa Island and the platforms fluctuated daily, indicative of individuals moving in and out of the receiver array, or around habitat that may have occluded signal transmission.

Lowe et al. (2009) observed a similar rate of emigration after releasing tagged rockfishes and lingcod at their platforms of capture. Ten days after their release, there was a rapid decrease in the number of fishes detected, followed by a slower decline through the duration of the study. We attributed the slow decline to emigration, as fishes moved from one platform to another, or away from areas of detection. Lowe et al. (2009) suggested that, over time, rockfishes likely emigrated away from platforms to other unmonitored locations, which may partially explain the disappearance of individuals in the current study.

Homing

The seafloor topography between Anacapa Island and Platforms Gail, Gilda, and Grace is largely a stretch of soft sediment with depths exceeding 230 m, presenting a large expanse of open water over relatively small patches of hard substratum. Notably, the homing distances observed in this study are the farthest reported for lingcod, vermilion and brown rockfishes. It is not known whether these fishes swam along the seafloor while homing or whether they traveled midwater or near the surface. Nevertheless, traversing these distances poses a greater challenge and risk, especially for relatively small fish, when crossing deep open water, than when following habitat along a coastline.

With the exception of one individual, all vermilion and the brown rockfish that homed were likely mature (range 27.5–35.3 cm TL). Vermilion rockfish mature as early around 31 cm (~ 4 yr), while 50% of brown rockfish are mature between 24 and 31 cm (~ 4–5 yr) (Love et al. 2002). Smaller, younger fish tend to occupy larger areas than adults that have established home ranges or territories (Larson 1980a; Lowe and Bray 2006) and are therefore expected to move more. In addition, they typically make ontogenetic shifts to deeper water as they mature (Love et al. 1991; Lowe et al. 2009), but not necessarily across long stretches of open water. However, smaller individuals that were translocated in this study tended not to home, and instead took up residency at Anacapa Island, or were not detected. Results indicate that among adults, individuals have variable propensities to home, while subadults showed a much lower probability of homing. Younger individuals may not develop an ability to home until they grow larger (Mathews and Barker 1983), or predation risk may be too high for subadults to leave a suitable, complex habitat offered by Anacapa Island. As they mature, fish may require additional resources that may compel them to shift their home ranges (Lowe and Bray 2006). For example, temporarily leaving a home range or territory to increase frequency or

probability of social interactions, such as spawning (Topping et al. 2006; Mason 2008), and being able to return is important for the success of some populations.

All fish that homed did so relatively quickly, leaving Anacapa Island after an average of 14.7 d following their release and taking from less than 24 h to travel back to the platforms. Compared to previous experiments displacing rockfishes, results from the current study revealed not only how quickly lingcod and rockfish can recover from catch, release, and tagging stress, but also the speed at which they orient themselves to a new environment and navigate home. Matthews (1990a) actively tracked copper and quillback (*S. maliger*) rockfish after displacing them 500 m from their home site and found that these species also homed quickly after release—after just 1–5 d. After translocation, short presence times at the site of release may be explained by a strong proclivity to home, or competition with resident fishes. Because of the protection offered inside the marine reserve, rockfishes at the site of translocation at Anacapa Island were not subjected to fishing mortality, which may have otherwise provided available space for new residents. This area of reef may have had well-established residents with territories, which could influence establishment of new colonizers (Larson 1980b) or it is possible that translocated individuals were able to assess the habitat quality simply preferred platform habitat over the natural habitat available. It is also possible that more individuals attempted to home, but either could not successfully navigate back to their platform, found more suitable habitat (unmonitored), or died trying to return.

The time of day and season during which homing occurred varied, but the departure time from the platforms after fish homed may have coincided with reproductive periods. Five vermilion rockfish (all adults) left Platform Grace between 25 Oct. and 16 Nov., and one lingcod left Platform Gail on 6 Feb. Although it was not known where these fish may have moved, all departed during a time that correlates with spawning season for these species (Love et al. 2002). Lowe et al. (2009) recorded an adult lingcod departing from Platform Gail and arriving in shallow water (~ 20 m) at Santa Cruz Island (9 km away) in mid-January. The same individual was detected again at Platform Gail only two days later. It was hypothesized that this was a female moving into a shallow reef to spawn, as this is a characteristic behavior for females of this species (Love 1996). Typically, adults that leave for spawning return to their home ranges. If their departure from the platforms was for spawning, then the five vermilion rockfish and one lingcod in this study should have been detected again by March or April. The absence of detections (presumably a failure to return) at the platforms may indicate that they left for purposes other than spawning, moved to different locations after spawning, or died trying to return.

Non-homing fishes

Two rockfishes (bocaccio, SPAU 3772 and widow rockfish, SENT 3753) that left Anacapa Island were detected for short periods of time at Platform Gail before apparently traversing back to Anacapa Island and subsequently falling out of detection altogether. This behavior may be representative of fish that left Anacapa Island to home, but were either unsuccessful, or moved to other unmonitored areas. Although they did not home, this bocaccio and widow rockfish were able to navigate between natural and platform habitat, a distance covering at least 22 km over open water. Homing has not previously been reported for bocaccio or widow rockfishes, but Hartmann (1987) reported long-distance movements of juvenile bocaccio (recaptured up to 148 km away) tagged from an oil platform in the north Santa Barbara Channel. Bocaccio are capable of long-distance movements and may even be able to home, but did not exhibit this behavior

in the current study. Hartmann (1987) also tagged widow rockfish, but none were recaptured away from their tagging sites, which would imply that this species exhibits strong site fidelity. Lowe et al. (2009) also found that widow rockfish have high site fidelity to offshore platforms.

Movements between platforms and Anacapa Island

It is not clear why lingcod and vermilion rockfish make such large migrations between platforms and natural habitat. Fishes may be forced to leave their home ranges for periods of time due to changes in water conditions, food resources, spawning, competition, or habitat quality, among other factors (Lowe and Bray 2006). Home range sizes were not quantified in this study, but movements of vermilion rockfish and lingcod away from home platforms with subsequent returns indicates that platforms may be important components of their habitat.

While it is not always clear what compels fish to move when they do, a behavioral response such as homing may confer a fitness advantage for a species. The movement of fish between platforms, and between natural habitat and platforms suggests that the risks associated with leaving protective habitat (e.g. predation, disorientation, loss of habitat) and traversing great distances outweigh the benefits of staying. Alternatively, the frequency of homing events might also indicate that the risks of leaving are low. Variation in temporal and spatial patterns of homing, movements and area use within and among species in this study illustrates behavioral plasticity present in adult rockfish and lingcod populations around offshore oil platforms; this, among other factors, may reduce competition and contribute to population stabilization.

Management

While this movement behavior has not previously been quantified, its implications for offshore oil platform decommissioning in California should be taken in consideration. Based on the longer-term patterns in detection after release, rockfishes and lingcod could indeed, be successfully translocated. While it may work better for some species (e.g. widow, squarespot, blue rockfishes) than others (e.g., lingcod, vermilion, and brown rockfishes) the success of a large-scale translocation would depend on a multitude of biological and logistical factors, such as the size of individuals, condition and care in handling of the fish, timing of platform removal and financial costs. Because a proportion of fishes (25% overall) homed back to platforms and did so quickly after release (23 d), translocation for individuals with inclinations to home would reduce the conservation benefits. Nonetheless, the greater proportion of fishes that did not home back to platforms would potentially be salvaged from the impacts of platform removal. Concurrently, translocation as a mitigation option could provide other biological benefits, such as reseeding depleted groundfish habitats, while rebuilding natural stocks.

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